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Posttraumatic Stress Disorder Symptoms, Physical Health, and Health Care Utilization 50 Years After Repeated Exposure to a Toxic Gas[1]

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The posttraumatic sequelae of contaminant exposure are a contemporary international concern due to the threats posed to military personnel and civilians by war and bioterrorism. The role of PTSD symptoms as a mediator between potentially traumatic toxin exposure and physical health outcomes was examined with structural equation modeling in a probability sample of 302 male World War II-era U.S. military veterans 50 years after exposure to mustard gas tests. Controlling for age and psychological distress, the most parsimonious structural model involved PTSD symptoms mediating the relationship between toxin exposure and physical health problems, and physical health problems mediating the relationship between PTSD symptoms and outpatient health care utilization. Implications for researchers, mental health clinicians, and health care providers are discussed.

KEY WORDS: PTSD; health; military veterans; toxic exposure; older adults.

Exposure to traumatic stressors and posttraumatic stress disorder (PTSD) have been found to be associated with self-reported medical problems, health-related functional impairment, and health care utilization in civilian samples of adults in the community, medical patients, female sexual assault survivors, and adult survivors of child abuse, as well as among military veterans (Schnurr & Green, 2003). A smaller number of studies (Green & Kimerling, 2003) have tested the hypothesis advanced by Friedman and Schnurr (1995) that PTSD symptoms mediate the effects of trauma exposure on physical health. PTSD symptoms are potentially enduring sequela of trauma exposure that are associated with dysregulation of the neuroendocrine, neurotransmitter, and autonomic and central nervous systems which can significantly compromise physical health (Schnurr & Jankowski, 1999). Consistent with this view, Kimerling, Clum, and Wolfe (2000) used correlation and regression analyses to demonstrate that PTSD symptom severity mediated the relationship of trauma exposure with Vietnam veterans' self-reported health status and acute health problems.

A more direct test of the mediation hypothesis is provided by analytic methodologies that delineate the direct and indirect pathways from trauma to physical health outcomes. As in regression analyses, potential covariates that may account for physical health outcomes (e.g., age, socioeconomic status, health risk behaviors) can be included to avoid spurious results. Path analyses provide greater clarity than regression by producing estimates of the effect of each hypothesized relationship among a set of variables,

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including both the direct effect between two variables and the indirect effect when a third variable mediates the relationship. For example, Friedman and Schnurr (1995) found that although war-zone exposure was directly associated with self-reported health or health problems among female Vietnam veterans, the indirect path from war-zone exposure through PTSD accounted for the majority (i.e., 56–76%) of the relationship between war-zone exposure and health outcomes.

Three recent studies tested several potential paths between trauma exposure, PTSD symptoms, and physical health outcomes. Taft, Stern, King, and King (1999) found that Vietnam veterans' combat exposure, social support, and psychological hardiness had weak effects on self-reported health and health-related impairment in psychosocial functioning, in each case mediated by PTSD symptoms. They also showed that health problems mediated the relationship between PTSD symptoms and health-related functional impairment. Schnurr and Spiro (1999) also found that older male military veterans' combat exposure was indirectly (but not directly) related to their self-reported physical health and functional status, mediated primarily (i.e., 90+%) by PTSD symptoms.

Several questions left unanswered by these studies were addressed in the present investigation. We interviewed a representative sample of male army and navy veterans who served in World War II and were intentionally exposed to toxic mustard gas in secret military tests (Pechura & Rall, 1993). This potentially traumatic stressor provides a strong test of the effects of trauma exposure and PTSD symptoms on physical health because it caused immediate adverse physical reactions that involved both immediate physical harm and pain (i.e., severe burns to the skin and eyes) and the potentially traumatic threat of severe long-term medical problems or premature death (Pechura & Rall, 1993). In a population-based study of this mustard gas test cohort, we have previously reported a 32% prevalence of current PTSD and 10% of "partial" PTSD related specifically to mustard gas test experiences (Schnurr, Ford, et al., 2000). Both full and partial PTSD were associated with physical health problems, health-related functional impairment, and outpatient (but not inpatient) health care utilization. Two measures of the extent of exposure to the toxic gas (i.e., the number of exposures; the severity of immediate physical symptoms) were associated with elevated risk of full PTSD independently of the effects of several other potential risk factors. We did not, however, examine the association between exposure and physical health outcomes, nor the potential role of PTSD as a mediator.

Therefore, in order to extend our prior findings and to contribute to the literature on the role of PTSD as a mediator between trauma exposure and health outcomes, we developed a conceptual model (Fig. 1) that includes a systematic mapping of direct and indirect paths that prior studies have tested only partially. We based the path model on an integration of several complementary theoretical perspectives that describe potential links between stress, coping and self-regulation, and physical health outcomes. Lazarus's (1993) appraisal and coping theory defines coping as a process of appraising stressors in ways that facilitate effective behavioral responses to the "main threat meanings" (p. 244). Effective coping "is capable of mediating the emotional outcome" (p. 239), potentially facilitating several outcomes that are associated with reduced physical health complaints and illness: enhanced "psychological resources" (e.g., optimism; Taylor, Kemeny, Reed, Bower, & Gruenewald, 2000) and self-regulation (Scheier & Bridges, 1995), and diminished negative affect (Watson & Pennebaker, 1989) and health risk behaviors (e.g., smoking, alcohol use; Breslow & Breslow, 1993). PTSD is associated with negative appraisals of stressors (Foa, Ehlers, Clark, Tolin, & Orsillo, 1999), reduced psychological resources (Hobfoll, 1998), avoidant coping (Bleich, Gelkopf, & Solomon, 2003), increased negative affect (Zoellner, Goodwin, & Foa, 2000), and health risk behaviors (e.g., alcohol use; Bleich et al., 2003). PTSD also is associated with self-reported physical health symptoms after controlling for stressful events and negative affect (Zoellner et al., 2000). Therefore, the role of PTSD as a potential mediator of exposure to (traumatic) stressors and negative physical health outcomes is warranted.

On the basis of this theoretical perspective, we constructed a model which included covariates that have been linked to both PTSD and poor physical health, specifically: age (Ford et al., 2001; Schnurr & Spiro, 1999; Wolfe et al., 1999), and mental health impairment (Asmundson, Stein, & McCreary, 2002; Clum, Calhoun, & Kimerling, 2000; Koss, Figueredo, & Prince, 2002). The model also included health risk behaviors associated with PTSD, specifically: smoking (Beckham et al., 1995; Boscarino, 1997; Schnurr & Spiro, 1999), and alcohol use (Asmundson et al., 2002; Ford et al., 2001). In order to fully represent physical health outcomes, the model included separate latent variables representing (a) physical health problems (Boscarino, 1997; Ford et al., 2001), (b) health-related functional status (Felitti et al., 1998; Ford et al., 2001; Schnurr & Spiro, 1999), and (c) two levels of intensity (i.e., inpatient and outpatient) of medical health care utilization (Marshall, Jorm, Grayson, & O'Toole, 1998; Schnurr, Friedman, Sengupta, Jankowski, & Holmes, 2000; Williams, Weiss, Edens, Johnson, & Thornby, 1998).

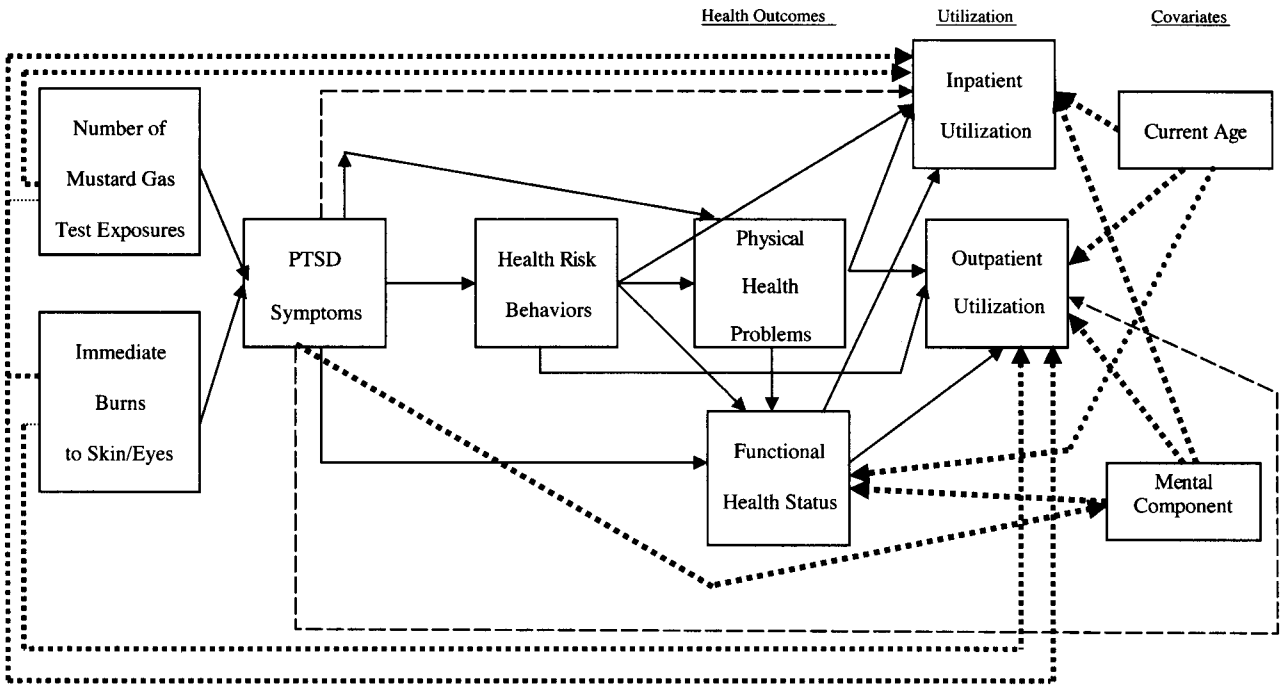

Fig. 1. Hypothesized path model between toxin exposure (number of mustard gas test exposures and immediate physical reactions), PTSD symptoms, health outcomes, and health care utilization, including two covariates potentially associated with health outcomes and health care utilization (current age; psychological distress assessed by the SF-36 mental component score). Unbroken lines indicate hypothesized mediated paths between PTSD symptoms and physical health outcomes and health care utilization. Dashed lines indicate direct paths from toxin exposure and PTSD symptoms to health care utilization. Dotted lines represent paths involving the covariates.

We applied a structural equation paradigm to test alternative versions of the conceptual model. We first addressed the question of whether both direct and indirect paths exist between the components of the conceptual model. To do this, we modeled all direct paths linking toxic exposure (i.e., number of exposures; severity of immediate physical symptoms) and PTSD symptoms with health care utilization (dashed-lines in Fig. 1), as well as all indirect (mediated) paths (unbroken lines) and the effects of covariates (dotted lines). Secondly, we tested a more parsimonious model that removed the direct paths between toxic exposure and the most distal physical health outcome (i.e., health care utilization), but retained the direct (dashed lines) and mediated paths (unbroken lines) from PTSD symptoms to physical health outcomes, and effects of covariates (dotted lines). Finally, we tested a fully mediated model, removing all direct paths to utilization but retaining the mediated (unbroken lines) and covariate (dotted lines) relationships. This final model allows us to determine if mediated paths from (a) exposure to PTSD symptoms, (b) PTSD symptoms to physical health problems and functional health impairment, and (c) physical health problems and impairment to health care utilization, can account for the links between trauma, PTSD, and health outcomes.

Method

Sample

As described in Schnurr, Ford, et al. (2000), participants were randomly sampled from a national registry of mustard gas test veterans conducted by VA's Office of Public Health and Environmental Hazards. Those alive as of October 1995 comprised the study population. Of an initial sample of 250 Army and 250 Navy veterans, 73% participated (N = 363, 166 Army and 197 Navy). Proportions of Army and Navy veterans in the final sample were almost identical to the proportions in the registry still alive at the time the sample was drawn. For the present study, 61 participants were excluded due to missing data on at least one variable in the path model, resulting in an effective N = 302 (139 Army and 163 Navy). Most missing data were from the physical health component score of the SF-36 (i.e., 54 of 61 participants with missing data). Excluded and included respondents did not differ on independent sample t tests (assuming unequal variances) or chi-square tests on any variable used in the path models (including severity of PTSD symptoms and all of the health variables). Those not included in data analyses due to missing data differed very little from the final sample

on demographics, and only in two respects: excluded respondents were less likely to be White (91%)—but there was no difference in the proportion of Hispanics—and less likely to be married (71%). Average age in the final sample was 71.7 years ($SD = 4.0$). Most were White (99%), and 10% indicated some Hispanic ethnicity. Most were married (86%) and had graduated from high school (63%). Most (79%) were retired, 12% were employed, and 9% were unemployed or unable to work.

Procedure

Data were collected over a 4-month period in 1996 by a telephone protocol administered by a survey research firm that had conducted PTSD telephone survey studies with the same or similar measures (e.g., the National Vietnam Veterans Readjustment Survey). Participants were informed about the study by letter. Interviews were conducted according to a protocol approved by the Department of Veterans Affairs (VA) Office of Environmental Health and Epidemiology to ensure informed consent and confidentiality. Interviews lasted approximately 40 min. All measures were brief to minimize respondent burden, selected based upon psychometrics or past use in large scale studies with comparable survey methodologies and samples. Although interviewers were highly trained and experienced, they were not clinicians and we wanted to avoid the unreliability associated with clinical judgments. Therefore, interviews were done using computer-assisted scripts that were carefully pilot tested for comprehensibility and for their ability to elicit definite answers.

Measures

Number of Exposures to Mustard Gas Tests

The extent of mustard gas exposure was measured as the self-reported number of mustard gas tests undergone, collapsed into two categories based on prior findings of a risk relationship between exposure and PTSD (Pechura & Rall, 1993): two or fewer exposures or did not recall (coded as 0), and more than two exposures (coded as 1).

Immediate Burns to Skin/Eyes

Participants were asked whether they had experienced the physical reaction that is established as a primary indicator of mustard gas toxicity—skin or eye burns (Pechura & Rall, 1993). An affirmative answer was coded 1. An answer of "No" was coded 0.

PTSD Symptoms

Current PTSD symptom severity was measured by the PTSD checklist (PCL; 1997). The PCL (Weathers, Keane, King, & King, 1997) consists of 17 items representing PTSD symptoms defined by the *Diagnostic and Statistical Manual* (4th ed.) of the American Psychiatric Association (1994). Respondents indicate the degree to which they were bothered in the past month by each symptom on a 5-point scale ranging from 1 (*not at all*) to 5 (*extremely*). Responses were averaged and multiplied by 17 to create a single current PTSD symptom severity score (coefficient $\alpha = .97$). All respondents with fewer than 25% missing items were included.

Health Risk Behaviors

Smoking history was measured by the single item "Did you ever smoke cigarettes for at least 10 years? (Yes/No)," selected to provide an estimate of relatively persistent smoking that would be minimally biased by recall error or demand characteristics. The degree of past problems with alcohol was measured with a four-item index comprised of three of the four CAGE (Adams, Barry, & Fleming, 1996) items with the substitution of a question for perceived problems with drinking (lifetime) replacing the CAGE question on guilt about drinking. Each item was worded with affirmative responses indicating an alcohol problem (e.g., "Have you ever felt you should cut down on your drinking?"). The score on the health risk behavior index was a count of the number of "Yes" responses across the smoking and alcohol items (range = 0–5).

Physical Health Problems

The number of physical health problems was assessed by self-report of 11 physical illness conditions (e.g., dermatologic, lung, heart, stroke, opthalmologic) derived from the National Survey of Veterans (National Center for Veteran Analysis and Statistics, 1995), with the score a tally of the number endorsed (0–11). Reliability and validity data have not been reported, but the measure is comparable to indices used in national surveys and research studies of veterans' physical health to assess the most reliably reported disease-related physical problems (Boscarino, 1997; Kimerling et al., 2000; Wolfe et al., 1999).

Functional Health Status

Functional health status was measured by the SF-36 (Ware, Gandek, & the IQOLA Project Group, 1996).

The SF-36 is a 36-item questionnaire that consists of four scales that primarily reflect physical health (Physical Functioning, Role Limitations due to Physical Problems, Pain, and General Health Perceptions) and four scales that reflecting mental health (Vitality, Social Functioning, Role Limitations due to Emotional Problems, and Mental Health). We used the Physical Component score to provide a single aggregate index of functional health status adjusted for (i.e., orthogonal to) the SF-36 Mental Component score (see below; Schnurr & Spiro, 1999; Ware et al., 1996).

Health Care Utilization

Inpatient health care utilization was measured with two items from the Normative Aging Study (Schnurr, Spiro, & Paris, 2000) assessing inpatient stays in the past 6 months in a hospital or emergency room (i.e., endorsement of either vs. denying both). Most respondents (~80%) reported no inpatient care during the prior 6 months, so to reduce skewness this variable was transformed by taking the inverse of the number of admissions (Tabachnick & Fidell, 2001).

Outpatient health care utilization was measured as a sum of the number of times participants reported (a) seeing a medical doctor or nurse during the past 6 months for shots, X-rays, or an examination, and (b) seeking medical advice from a doctor or nurse over the phone during the past 6 months. This variable also was skewed, though not to the same degree as inpatient utilization, so a logarithmic transformation was used to reduce skewness (Tabachnick & Fidell, 2001).

Covariate Measures

Three variables were examined as potential covariates. Age was recorded in chronological years. Psychological distress was measured using the Mental Component score from the SF-36 (Ware et al., 1996). A third potential covariate, health-related disability, was not included in the multivariate model due to a nonsignificant bivariate correlation with the utilization variables.

Data Analyses

First, summary statistics and bivariate correlations were calculated. Next, the hypothesized path model specifying the relationships among the observed variables depicted in Fig. 1 was tested using LISREL 8 (Joreskog & Sorbom, 1993). A variance/covariance matrix served as input to the program (Cudeck, 1989) and model estimation was based on General Least Squares estimation procedure appropriate to the *n* (Hu, Bentler, & Kana, 1992). Several fit indices were used to evaluate overall fit of the model, including the nonnormed fit index (NNFI), the normed fit index (NFI), the comparative fit index (CFI; Bentler, 1990), and the root mean square error of approximation (RMSEA; Steiger, 1990). NNFI, NFI, and CFI values of .90 or greater indicate adequate fit of the model to the data. RMSEA values of .05 or smaller indicate acceptable fit (Browne & Cudeck, 1993). *t* tests > 2.0 ($p < .05$) were used to evaluate significance of individual paths. The chi-square difference test was used to compare the models (Anderson & Gerbing, 1988).

Results

Table 1 displays descriptive information for all variables. As can be seen, for those variables that were not categorical, the observed ranges were nearly identical to the possible ranges, suggesting that range restriction was not a problem.

Bivariate correlations are presented in Table 2. As predicted, both number of test exposures and immediate burns were correlated with PTSD symptoms. Number of test exposures (but not immediate burns) also correlated with medical problems, functional health status, and inpatient health care utilization. PTSD symptoms were strongly related to physical health problems and functional health status, and somewhat less but still significantly related to inpatient and outpatient utilization. Physical health problems and functional health status were correlated with each of the health care utilization variables. These correlations are consistent with the proposed mediational model linking (a) toxin exposure, (b) PTSD symptoms, (c) health status, and (d) health care utilization.

Table 1. Descriptive Statistics for Mustard Gas Test Exposure, PTSD, and Health Outcome Variables

Variable	Mean	*SD*	Observed range	Possible range
Frequency of exposure	0.53	0.50	0–1	0–1
Skin/eye burns	0.79	0.40	0–1	0–1
PTSD symptoms	35.19	18.29	17–80	17–85
Health risk	1.16	1.10	0–5	0–5
Current age	71.69	3.99	67–87	
SF-36 mental component	44.59	12.64	14.93–68.81	
Formal disability status	0.99	0.11	0–1	0–1
Physical health problems	4.68	2.17	0–11	0–11
Functional health status	34.05	11.50	14.26–58.58	
Inpatient utilization	0.84	0.29	0.05–1	0–1
Outpatient utilization	0.58	0.36	0–1.59	

Note. $n = 302$ based on listwise deletion of missing data; an inverse transformation was applied to inpatient utilization; a logarithmic transformation was applied to outpatient utilization.

Table 2. Intercorrelations Among Mustard Gas Test Exposure, PTSD, and Health Outcome Variables

	1	2	3	4	5	6	7	8	9	10
1. Number of exposures	—									
2. Immediate burns	.11	—								
3. Current age	−.23**	.10	—							
4. SF-36 mental component	−.17*	.06	.04	—						
5. Disability status	.06	.09	.02	.05	—					
6. PTSD symptoms	.22**	.14*	−.11	−.69**	.01	—				
7. Health risk	.07	.04	−.03	−.11	.04	.05	—			
8. Physical problems	.23**	.10	−.13*	−.43**	.04	.48**	.07	—		
9. Functional status	−.17	.00	.09	.37**	.04	−.53**	−.06	−.48**	—	
10. Inpatient utilization	.13*	.10	.04	−.26**	.00	.21**	−.05	.16*	−.21**	—
11. Outpatient utilization	.08	.07	−.02	.31**	.08	.27**	.03	.32**	.34**	.39**

Note. $n = 302$ based on listwise deletion of missing data; An inverse transformation was applied to inpatient utilization, so correlations involving this variable have +/− signs reversed to reflect actual relationships; A logarithmic transformation was applied to outpatient utilization.

*$p < .05$, two-tailed. **$p < .01$, two-tailed.

All correlations involving the health risk behavior index of smoking history and alcohol problems—with PTSD symptoms and with each health outcome—were statistically nonsignificant.

The test of the overall fit of the full model depicted in Fig. 1 indicated that this model fit the data reasonably well. Both the NFI and NNFI were .98, the CFI was .99 and the RMSEA was .052, $\chi^2(14, N = 302) = 25.23$, $p < .05$. All of these suggest that the model fit the data reasonably well. However, a second model that removed the direct paths from mustard gas exposure and immediate burns to skin/eyes to the utilization variables fit the data equally well. The NFI and NNFI were .98, the CFI was .99 and the RMSEA was .053, $\chi^2(18, N = 302) = 32.86$, $p < .05$. The fit of the models did not differ, $\chi^2(4, N = 302) = 7.63$, $p > .05$. A final model removed the direct paths from PTSD to outpatient or inpatient utilization, and again fit the data well. The NFI and NNFI were .98, the CFI was .99 and the RMSEA was .048. The chi-square (df = 20) was 33.50. The fit of the final and first models did not differ, $\chi^2(6, N = 302) = 8.27$, $p > .05$. The fit of the final and second models alsos did not differ, $\chi^2 < 1$. Thus, the most parsimonious fully mediated model fit as well as the alternative models. Results for specific paths (standardized path coefficients) in the model are presented in Fig. 2.

Beyond this, because a model may fit well even when the magnitude of the effects within it are not significant themselves, we also tested the significance of the indirect effects of the number of mustard gas test exposures and immediate burns to skin/eyes on physical health problems and functional health. The indirect effects for the number of mustard gas test exposures on health problems and functional health were both significant (effect size = .10 and −.12, $p < .05$, respectively). Similarly, the indirect effects for immediate burns to skin/eyes on health problems and functional health were also significant (effect size = .06 and −.06, $p < .05$, respectively).

Discussion

We (Schnurr, Ford, et al., 2000) previously reported the finding that, in a sample of older veterans who had been exposed to mustard gas tests, participants with symptoms severe enough to qualify for a PTSD diagnosis had very poor physical health and functioning and were high utilizers of health care. These new analyses with the same mustard gas test veteran sample suggest that, over a period of five decades or more, PTSD symptoms mediate the relationship between toxin exposure and physical health problems, impaired functioning, and outpatient health care utilization.

This is the first study to our knowledge that has systematically modeled the direct and indirect paths between trauma exposure, PTSD symptoms, health risk behaviors, physical health problems, physical health-related functional status, and outpatient and inpatient health care utilization. Our results show that a fully mediated model can account for the relationships between: (a) the extent of toxin exposure, (b) PTSD symptoms, (c) physical health problems and functional impairment, and (d) outpatient health care utilization. PTSD's role as a mediator between toxic exposure and adverse physical health outcomes held up after accounting for the effects of other potential risk factors for physical health problems and health care utilization (i.e., age, mental health problems, and health risk behaviors). Our findings replicate results of prior studies showing that PTSD symptoms mediate between trauma exposure and physical health problems, impaired functional status, and health care utilization (Green & Kimerling, 2003). Most prior studies involved midlife or young adults (with exceptions, e.g., Schnurr &

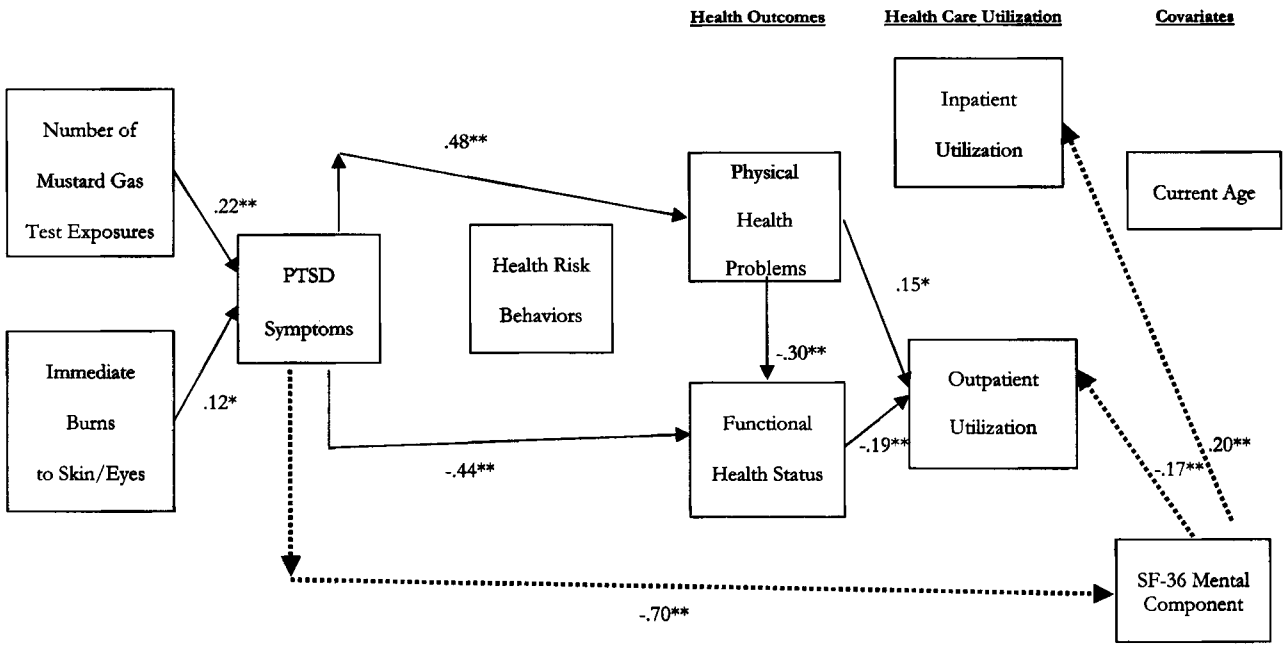

Fig. 2. Final path model showing mediated paths between toxin exposure, PTSD symptoms, physical health outcomes, and outpatient health care utilization, including the effect of a covariate representing psychological distress (the SF-36 mental component score). $^{*}p < .05$. $^{**}p < .01$.

Spiro, 1999) and focused on traumatic stressors that did not involve exposure to a physical health hazard such as toxic gas (with exceptions, e.g., Ford et al., 2001).

The testing of alternative structural models describing the paths between toxin exposure, PTSD symptoms, and other possible determinants of health outcomes (e.g., health risk behaviors; global psychological distress; age) enabled us to reduce the complex array of potential paths to a smaller number of paths that still account for the relationships between PTSD and health outcomes. Although the direct paths in the first two models were significant, the fit of the model when those paths were dropped supports a theoretical model in which PTSD symptoms serve as the link between trauma and illness (Friedman & Schnurr, 1995), and illness and impaired function serve as the link between PTSD symptoms and help-seeking (Schnurr, Friedman et al., 2000). Although other studies have examined the PTSD in relation to illness, functional health status, and health care utilization, our results demonstrate PTSD's mediational role simultaneously in all three domains of health outcomes. Our findings also are consistent with recent findings by Deykin et al. (2001) that physical health problems mediate the relationship between PTSD and health care utilization.

One way to understand and apply these findings is to view PTSD symptoms as what are described in Andersen's (1995) behavioral model of health care utilization as "predisposing factor." This model posits that the decision to use health care is a function of risk factors that predispose an individual biologically or psychosocially to become ill and to perceive illness symptoms as sufficient to warrant treatment. PTSD symptoms are associated with biological alterations in several bodily systems (e.g., central nervous, cardiovascular, and immunologic) that may profoundly compromise physical health (Boscarino, 1997). The exact relationship between PTSD symptoms and physical health problems remains to be established, but our findings suggest that they are a link between trauma exposure and adverse physical health outcomes—even when physical risk factors (e.g., toxic exposure; old age) are salient. This has clinical implications because PTSD symptoms can be alleviated (Foa, Keane, & Friedman, 2000) or mitigated (Harvey & Bryant, 2002) by specific psychological treatments. Therefore, identifying PTSD symptoms via screening (e.g., Breslau, Peterson, Kessler, & Schultz, 1999), and addressing them either directly or by referral to specialists, may enhance primary medical as well as mental health care for trauma survivors.

We also found that PTSD symptoms were indirectly associated with outpatient but not inpatient health care utilization. Prior studies typically have not separately assessed outpatient and inpatient utilization across all types of health care—instead combining outpatient with inpatient or only focusing on one type of health care

(e.g., Marshall et al., 1998; Williams et al., 1998). In this study, bivariate correlations suggested that PTSD symptoms were associated with inpatient utilization, but the multivariate structural model clarified that PTSD symptoms were linked only to outpatient utilization whereas more generalized psychiatric distress was related to inpatient utilization. Although requiring replication and prospective longitudinal evaluation, these findings suggest that PTSD symptoms may be particularly relevant to screen or assess in outpatient health care, and psychiatric distress may be most critical to assess among medical inpatients.

The findings are consistent with theoretical models that focus on reduced social and personal resources (Hobfoll, 1998) and impaired self-regulatory coping (Benight et al., 1999) as outcomes of PTSD. We found that PTSD symptoms were associated with poorer health-related psychosocial functioning and greater severity of physical health problems and psychological distress, but not with health risk behaviors. This raises the possibility that PTSD's impact on health may not be due to poor health-related coping per se (e.g., alcohol use) but instead to a more general loss of social or personal resources (Kaniasty & Norris, 2001) or a more generalized loss of coping self-efficacy (Benight & Harper, 2002). However, coping with the specific sequelae and ongoing effects of traumatic stressors also is compromised by PTSD (Bleich et al., 2003), and this may in turn lead to health risk behaviors (Bleich et al., 2003) and impaired functioning and health. Further investigation of the role of coping, resources, and coping self-efficacy as potential mediators of the relationship between PTSD and health outcomes is warranted.

Several limitations necessitate caution in interpreting our findings. Although the sample was representative of the population of interest (i.e., older, primarily Caucasian, male military veterans who had been exposed to toxic gas), the findings cannot be generalized beyond this specialized population without further research with broader age, gender, and ethnocultural samples from civilian as well as military populations. Replication with other types of toxic exposures or patients with chronic health problems is needed to confirm PTSD's role in severe physical illness. This study was cross-sectional, so no firm inferences can be made about the direction of causal associations between PTSD and physical health outcomes. However, the evidence of PTSD's mediating role for the relationship between prior traumatic events and current physical health outcomes is consistent with the growing empirical literature indicating that traumatic stress affects physical health. Prospective studies (e.g., Wolfe et al., 1999) are needed in order to more clearly disentangle nature and directionality of the relationship between PTSD and physical health.

To assess physical health problems, we relied upon retrospective self-report—which may differ from clinical findings (Felitti et al., 1998). To minimize *over*reporting, we inquired about the specific serious disease states (Boscarino, 1997) most likely to be sequelae of mustard gas (Pechura & Rall, 1993) or prevalent among older adults (Schnurr & Spiro, 1999). We relied upon self-report to assess health care utilization, which tends to be relatively accurate among older adults for inpatient care—but which older adults tend to *under*report (compared to medical record data) when asked to recall the number of outpatient visits in the past year (Roberts, Bergstralh, Schmidt, & Jacobsen, 1996; Wallihan, Stump, & Callahan, 1999). Therefore we used a shorter retrospective time frame (past 6 months) derived from the Normative Aging Study, and we transformed the utilization data in order to reduce the skewness in the distribution that reflected frequent endorsement of 0 or 1 visits and a small number of outliers reporting many visits. If underreporting occurred, this is more likely to have attenuated than inflated our findings—suggesting that the findings are robust. Nevertheless, studies with objective health indicators are needed to more definitively distinguish between the effects of PTSD on self-reported versus actual illness (Ford et al., 2001; Schnurr, Spiro, et al., 2000).

Our retrospective data regarding mustard gas exposure may be subject to recall bias due to the 50+ year time lag, and dichotomizing the variables may have reduced our ability to detect effects. Nevertheless, we found the predicted relationships between toxin/trauma exposure variables and PTSD, health outcomes, and health care utilization on both a bivariate and multivariate basis.

In conclusion, even when serious physical health risks have been present for decades as a result of exposure to a contamination stressor (Decouflé, Holmgreen, Boyle, & Stroup 1992; Green, Lindy, & Grace, 1994), PTSD symptoms may adversely affect physical health. Toxic biologic exposure can have a psychological impact in the form of PTSD symptoms as well as adverse physical effects, and the posttraumatic psychological sequelae may complicate or worsen physical illness and health-related functioning. Although PTSD symptoms cannot be said to cause medical illness, they may tax the body's protective and self-regulatory systems and thereby exacerbate illness while also reducing the individual's capacity to recover and function fully in life. When this happens, outpatient or inpatient health care utilization and their associated costs may be increased as a result of the patient's attempt to get help not only for physical symptoms but also for traumatic stress symptoms and psychological distress. Early

and accurate detection and treatment of PTSD symptoms thus may be an important clinical and fiscal concern for the health care system.

The assessment of the immediate and delayed posttraumatic sequelae of contaminant exposure is a clinical and scientific concern of particular relevance in light of current threats posed to both military personnel and civilians by current (and potential) wars and incidents of bioterrorism. The combination of exposure to physical toxins and psychological trauma appears to have had a major long-term impact on military personnel in the first Gulf War (Ford et al., 2001; Wolfe et al., 1999). In the twenty-first century, thousands more soldiers may be subject to toxic exposure and war trauma in Iraq and other war zones, and millions of civilians across the world live with the specter of toxic exposure and traumatic stress due to the ongoing threat of bioterrorism. As these perilous scenarios unfold over then next months, years, and decades, it will be crucial for scientists and health care professionals to understand and be able to proactively address the potential impact of the combination of toxin exposure and posttraumatic stress.

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